

Unit and Measurement

The comparison of any physical quantity with its standard unit is called Measurement.

Physical Quantities

All the quantities in term of which laws of physics are described, and whose measurement is necessary are called physical quantities.

Units

- A definite amount of a physical quantity is taken as its standard unit.
- The standard unit should be easily reproducible internationally accepted.

Fundamental Units

Those physical quantities which are independent to each other are called fundamental quantities and their units are called fundamental units.

1.	Length	metre	m
2.	Mass	Kilogram	kg
3.	time	second	s
4.	Temperature	Kelvin	K
5.	Electric current	ampere	A
6.	Luminous intensity	Candela	cd
7.	Amount of substance	mole	mol

Mechanical Properties of fluid.

Mechanics

Fluid : A fluid is a substance that can flow.

E.g: Both liquids and gases are fluid.

Fluid statics :-

The branch of physics that deals with the study of fluids at rest is called fluid statics or hydrostatic.

Its study includes hydrostatic.

pressure, pascal law, archimedes principle, floatations of bodies and surface tension.

Fluid Dynamics :-

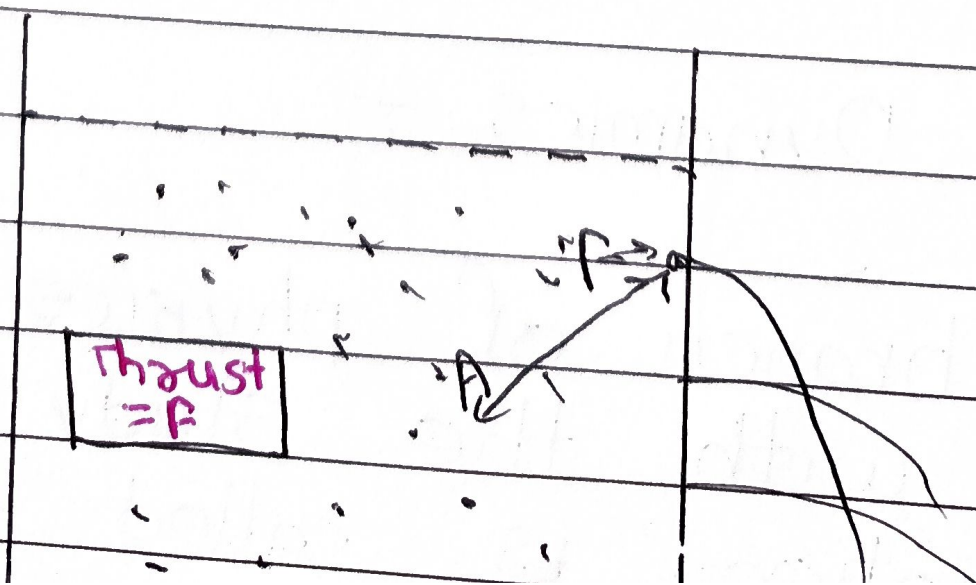
The branch of physics that deals with the study of fluids in motion is called fluid dynamics or hydrodynamics. Its

Study includes equation of continuity, Bernoulli's theorem, Torricelli's theorem, viscosity, etc

Thrust :

The total force exerted by a liquid on any surface in contact with it is called thrust.

It is because of this thrust that a liquid flows out through the holes of the containing vessel.



Pressure $\div$ (P)

The pressure at a point on a surface is the thrust acting normally per unit area around that point

$$P = \frac{F}{A}$$

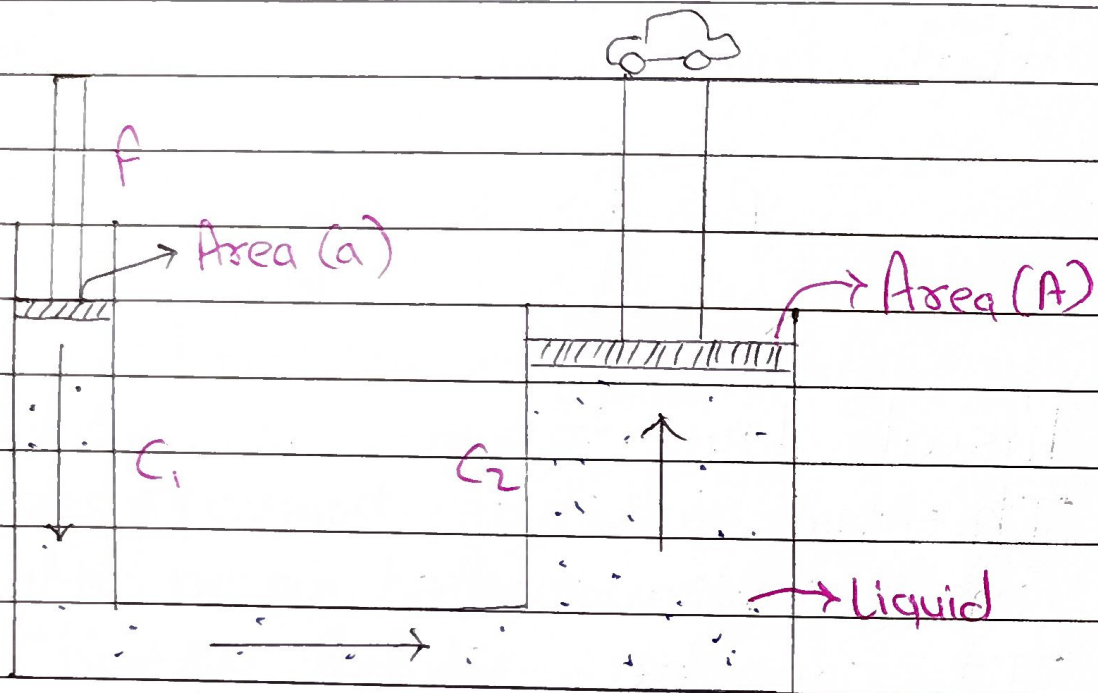
Pascal law $\div$

This law tells as how pressure can be transmitted in a fluid.

It can be stated as - "The pressure exerted at any point on an enclosed liquid is transmitted equally in all directions."

Application of Pascal Law :-

Hydraulic lift -



→ Pressure exerted on liquid = $\frac{F}{a}$

force on larger piston :

$$F \approx P \times A = \frac{F}{a} (A)$$

$$\therefore [a < A \Rightarrow F > P]$$

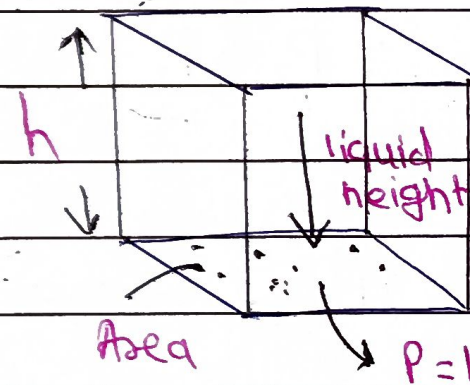
Pressure exerted by a liquid column :-

Consider a vessel of height 'h' and cross sectional area A filled with a liquid of density ρ as shown in the figures

weight of liquid column :-

$$W = \text{mass} \times \text{liquid} \times g$$

$$= (Ah)\rho g \quad \text{--- (1)}$$



Liquid Pressure

$$P = \frac{W}{A} = \frac{Ah\rho g}{A}$$

$$P = h\rho g$$

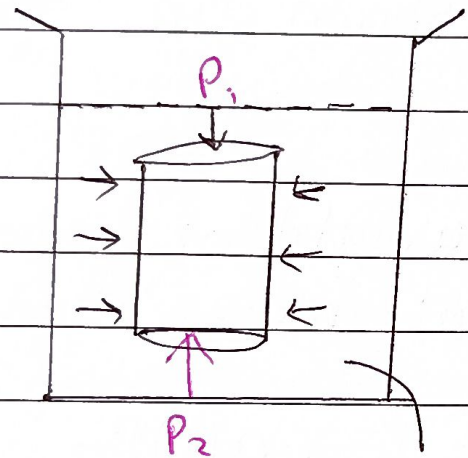
Variation of liquid pressure with depth.

$$P_2 = P_1 = h \rho g$$

$$P_2 = P_1 + h \rho g$$

$$P_1 = P_2 - h \rho g$$

$$\therefore [P_2 > P_1]$$



et if container is open

$$P_1 = P_a \text{ (atmospheric pressure)}$$

$$P_2 = P$$

$$P = P_a + h \rho g$$

$$(P - P_a) = h \rho g = \text{Gauge pressure}$$

If we neglect the effect of gravity :-

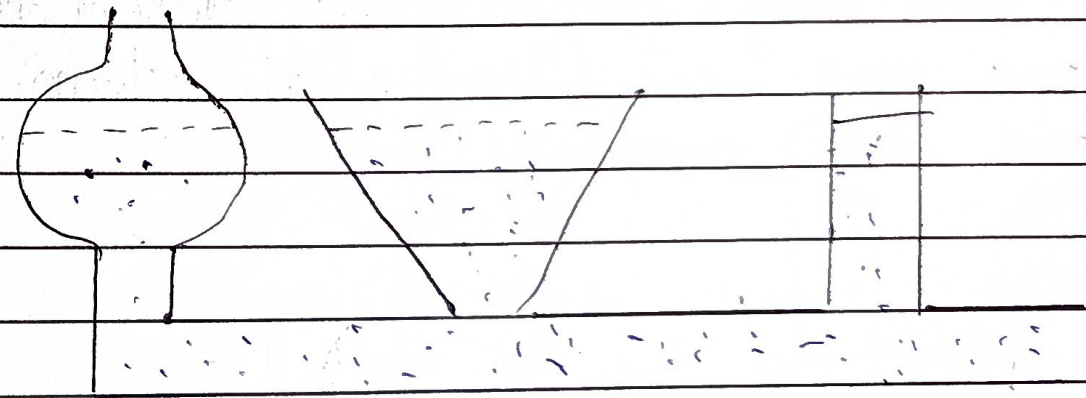
$$g = 0$$

$$P_2 - P_1 = 0$$

$$P_2 = P_1$$

i.e. pressure at all points inside the liquid is same in absence of gravity. This is Pascal law.

Hydrostatic Paradox :-



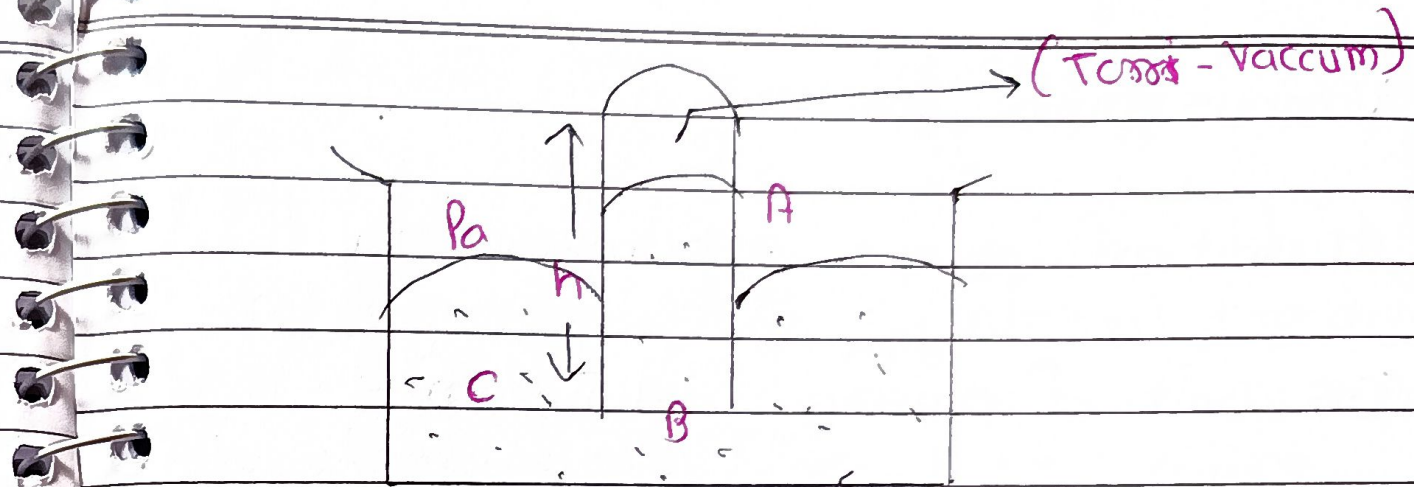
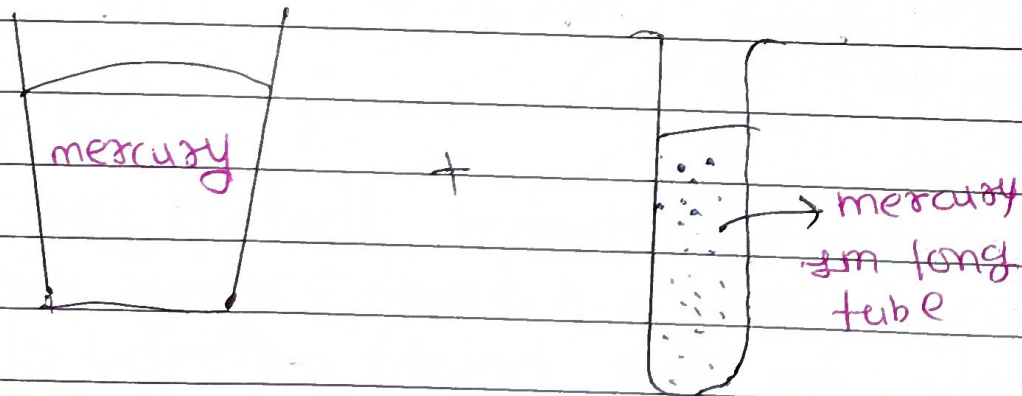
Pascal demonstrated that a pressure exerted by a liquid column depends only on the height of the liquid column and not on the shape

of the containing vessel. This is hydrostatic paradox

Mercury Barometer:

An Italian Scientist Torricelli was first to devise a method for measuring atmospheric pressure accurately. It is called simple barometer.

A 1m long glass tube closed at one end is filled with clean and dry mercury



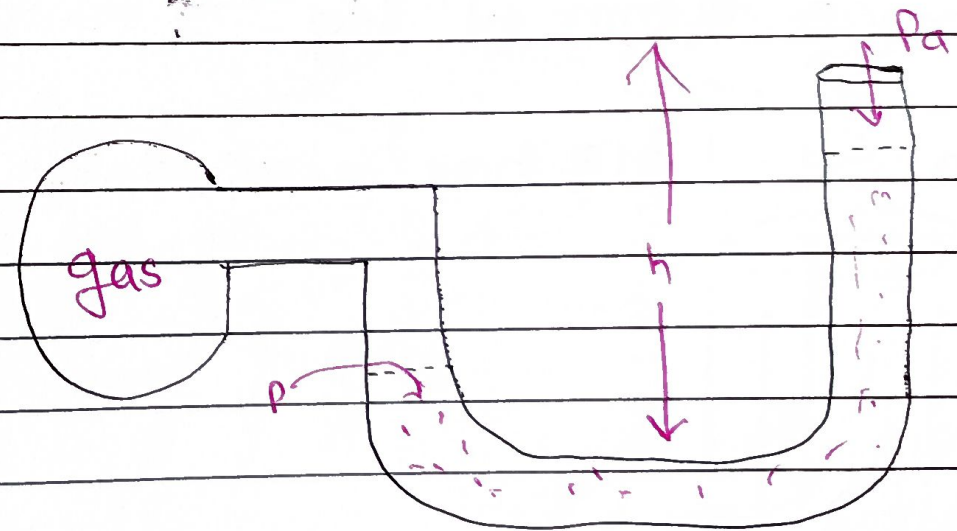
$$P_a = h \rho g$$

$$h = 76 \text{ cm}$$

$$\rho = 13.6 \times 10^3 \text{ kg/m}^3$$

$$g = 9.8 \text{ m/s}^2$$

$$P_a = 1.013 \times 10^5 \text{ Pa}$$



$$P = P_a + h \rho g$$

various units for pressure.

SI unit of pressure = N/m^2 or Pa

CGS unit of pressure = dyne/cm^2

1 atm = 1.013×10^5 Pa

1 bar = 10^5 Pa = 10^6 dyne/cm²

1 millibar = 10^{-3} Bar = 100 Pa

1 torr = 1 mm of Hg

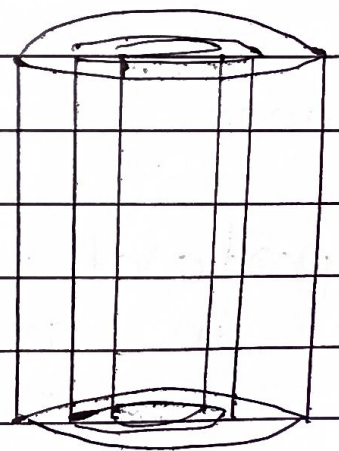
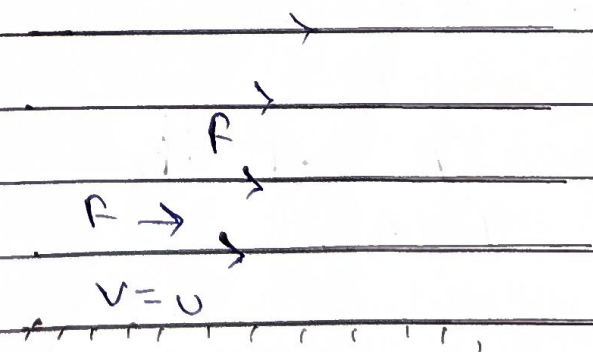
1 atm = 1.013 bar = 760 torr

Viscosity : (μ)

It is the property of liquid fluid by virtue of which internal force of friction comes into play when a fluid is in motion and which opposes the relative motion between its different parts.

The backward dragging force called viscous drag or viscous force act tangentially on the layers of the fluid in motion and tend to destroy its motion.

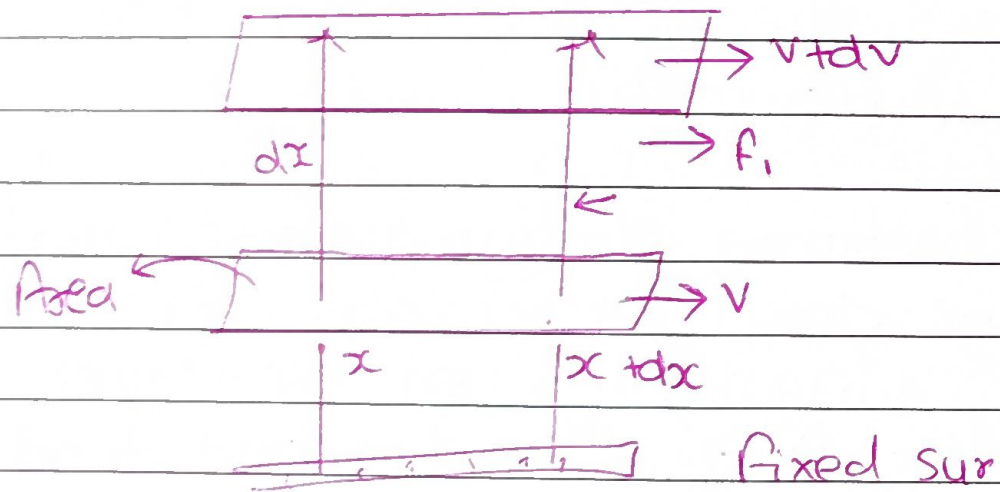
surface layer $v = \text{max}$



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Coefficient of viscosity :-

As shown in the figure suppose a liquid is flowing steadily in the form of parallel layer on a fixed horizontal surface



According to Newton a force of viscosity F acting tangentially between two layers is

i) Proportional to area (A) of the layer in contact $F \propto A$

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Proportional to velocity gradient $\frac{dv}{dx}$ between the 2 layers

$$F \propto A \frac{dv}{dx}$$

$$F = -\eta A \frac{dv}{dx}$$

η = Coefficient of viscosity

D.F of η :

$$\eta = \frac{F}{A} \cdot \frac{dx}{dv}$$

$$[\eta] = [ML^{-1}T^{-1}]$$

Unit = In CGS = dyne sec/cm² or gcm⁻¹s⁻¹

This is also called poise)

$$(1 \text{ poise} = 1 \text{ dyne sec/cm}^2)$$

In SI unit =

Newton sec/m² or kgm⁻¹ s⁻¹ (This is also called decapoise or poiseuille)

$$1 \text{ poiseuille} = 1 \text{ Newton sec/m}^2$$

Relationship betⁿ Poiseuille and poise :-

$$1 \text{ poiseuille} = 1 \text{ Newton sec/m}^2 = 10 \text{ poise}$$

Effect of Tempe. on Viscosity :-

→ The viscosity of a liquid decreases with the increase in temperature

→ Viscosity of a gas increases with temp.

Effect of Pressure on Viscosity.

Exept water the viscosity of a liquid increases with the increase in pressure. In case of water, viscosity decreases with the increase in pressure for first few hundred atmosphere of pressure.

→ The viscosity of gas is independent of pressure

Stoke's Law :-

According to Stokes the backward viscous force acting on a small spherical body of radius 'r' moving with uniform velocity 'v' through fluid of viscosity is given by -

$$F = 6\pi\eta r v$$

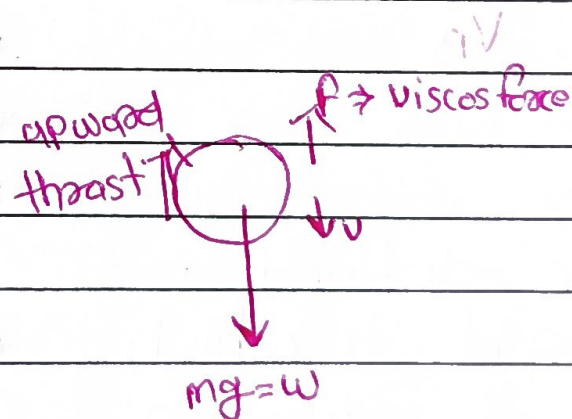
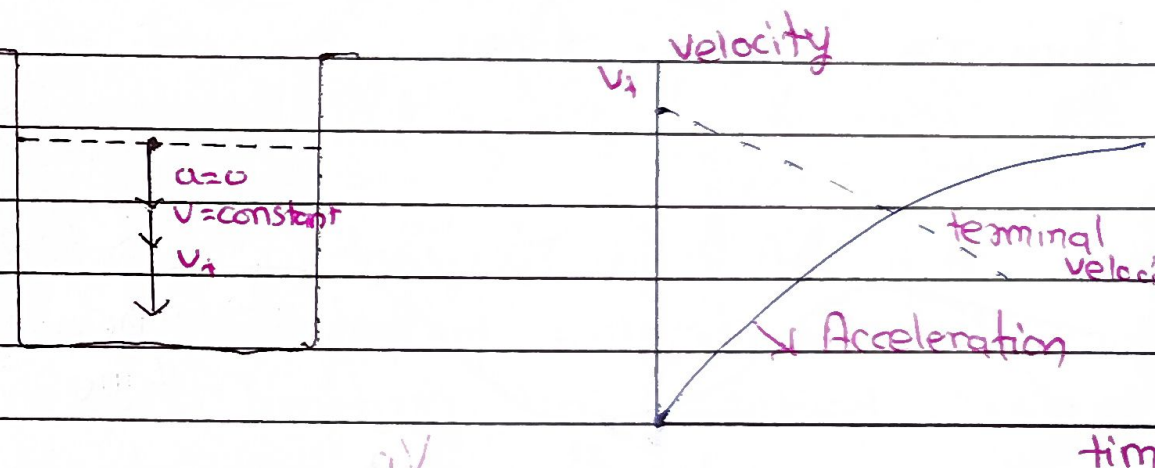
where r = radius of spherical body

v = velocity of - - -

η = coefficient of viscosity of liquid

Terminal Velocity (V_t) :-

The max constant velocity acquired by a body while falling through a viscous medium is called its terminal velocity.



$$V_t = \frac{2}{9} \frac{r^2(\rho - \sigma)g}{\eta}$$

ρ = density of spherical body

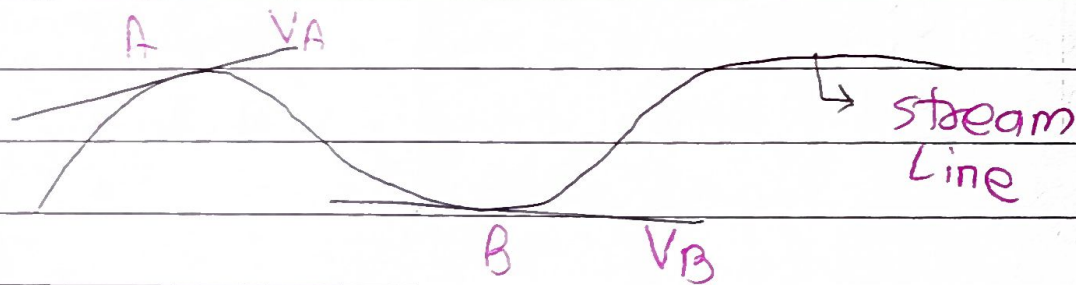
σ = density of liquid

r = radius

η = coefficient

Stream Line Flow

When a liquid flows such that each particle of liquid passing a given point moves along the same path and has the same velocity as its predecessors, the flow is called stream line flow or steady flow.

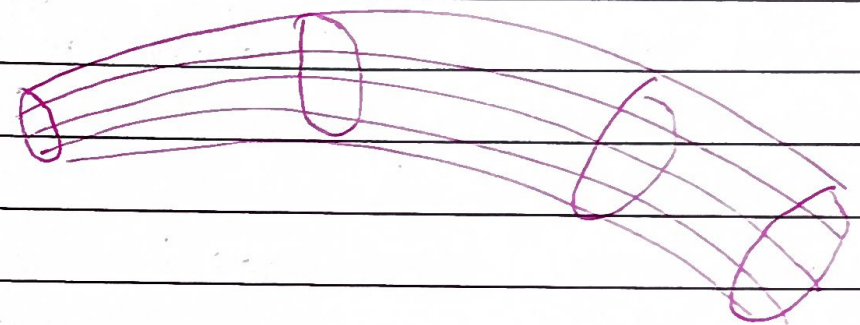


A streamline may be defined as the path, or the tangent to which at any point gives the direction of the flow of liquid at that point.

Tube

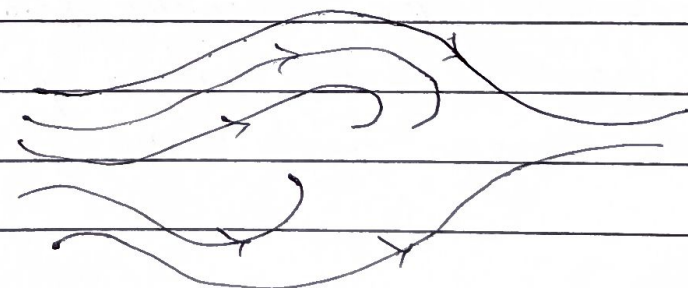
Tube of flow

A bundle of stream lines forming a tubular region is called a tube of flow.



Turbulent Flow :-

When the liquid velocity exceeds a certain limiting value called critical velocity, the liquid flow becomes zig-zag. The path and the velocity of a liquid particle changes continuously. This flow is called turbulent.



Properties of Stream lines :-

1. Tangent to the Velocity :

At any point on a streamline, the tangent gives the direction of fluid velocity at that point.

2. No Crossing streamlines :

Two streamlines never intersect each other. If they did, it would mean the fluid has two different velocities at the same point, which is not possible.

3. Steady flow Representation :

Streamlines represent the steady flow of a fluid; where velocity at a point does not change with time.

4. Density of streamlines.

Closer streamlines indicate higher velocity of the fluid and vice versa.

This is based on the principle of conservation of mass (continuity equation).

5. Imaginary Curves :

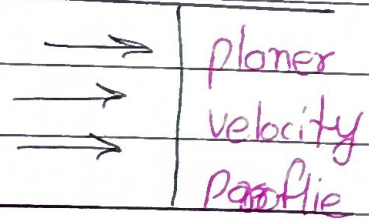
Streamlines are imaginary lines, used to visualize the motion of fluid particles.

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Laminar flow :-

When the velocity of the flow of a liquid is less than its critical velocity, the liquid flows steadily. Each layer of the liquid slides over the other layer, it behaves as if different lamina or sliding over one another, such a flow is called laminar flow.

Viscous fluid



Linear
velocity
profile

Non-viscous fluid



Parabolic
velocity
profile

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Critical velocity :-

The critical velocity of a liquid is that limiting value of its velocity of flow up to which the flow is streamline and the above which the flow becomes turbulent.

$$V_c = \frac{kN}{\rho D}$$

k = Reynold number

D = Diameter

Reynold number :-

It is a dimensionless parameter whose value decides the nature of flow of a liquid through a pipe

$$R = \frac{V_c S D}{\eta} = R$$

1) If R lies beth 0 ^{and} to 2000, the liquid flow is stream line

If ~~greater~~ than 3000, the liquid flow is turbulent

If R lies beth 2000 and 3000, the flow of liquid is unstable.

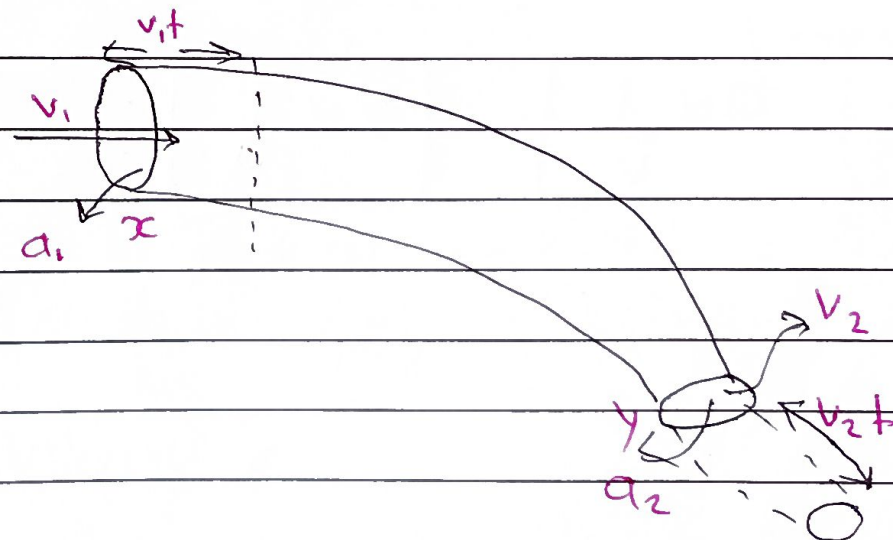
It may change from laminar to turbulent and vice-versa

Ideal Fluid :-

An ideal fluid one which is non viscous, incompressible and its flow is steady and irrotational

Equation of Continuity :-

It states that, during the stream line flow of the non viscous and incompressible fluid through a pipe of variable cross section, the product of area of cross section and the normal fluid velocity remains constant throughout the flow



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$$(\text{mass})_x = (\text{mass})_y$$

$$(\text{volume}) \times (\text{density})_x = (\text{volume} \times \text{density})_y$$

$$(\text{volume})_x = (\text{volume})_y$$

$$(a_1 v_1 t)_x = (a_2 v_2 t)_y$$

$$a_1 v_1 = a_2 v_2$$

$$av = \text{constant}$$

$a \propto \frac{1}{v}$

$v \propto \frac{1}{a}$

Energy of a fluid in flow :-

i) Kinetic Energy : (V)

The energy possessed by virtue of its motion is called kinetic energy.

→ K.E. per unit mass of liquid =

$$\frac{\frac{1}{2} mv^2}{m} = \frac{1}{2} v^2$$

$$\therefore KE = \frac{1}{2} mv^2$$

→ K.E. per unit weight of the liquid is known as the velocity head

$$\text{Velocity head} = \frac{\frac{1}{2} mv^2}{mg} = \frac{v^2}{2g}$$

K.E. per unit
volume = $\frac{1}{2} \rho v^2$

$$= \frac{1}{2} \rho v^2$$

2. Potential Energy:

The energy possessed by a liquid by virtue of its position above the earth surface is called its potential energy.

$$[P.E = mgh]$$

$$P.E \text{ per unit mass of liquid} = \frac{mgh}{m} = \boxed{gh}$$

P.E per unit weight of liquid is known as the potential head

$$\text{Potential head} = \frac{mgh}{mg} = \boxed{h}$$

$$P.E \text{ per unit volume} = \frac{mgh}{V} = \boxed{\rho gh}$$

$$\therefore \rho = m/V$$

3. Pressure Energy:

The energy possessed by a liquid by virtue of its pressure is called its pressure energy. A liquid under pressure can do work and so, possesses energy.

$$\rightarrow P.E \text{ per unit volume} = [P \text{ (Excess Pre)}]$$

$$\rightarrow \text{Pressure Energy per unit mass} = P/\rho$$

$\rightarrow$ Pressure E. per unit weight of the liquid is called pressure head =

$$\frac{P}{\rho gh}$$

Bernoulli Principle :-

• It states that the sum of pressure energy, K.E and P.E per unit volume of an incompressible, non-viscous fluid in a streamline irrotational flow remains constant.

• Mathematically it can be expressed by

$$P + \frac{1}{2} \rho v^2 + \rho gh = \text{Constant}$$

The formula can be written as

$$\frac{P}{\rho g} + \frac{v^2}{2g} + h = \text{Constant}$$

This is the another form of Bernoulli principle according to which the sum of pressure head, velocity head and gravitational head remains constant in the streamline flow of an ideal fluid.

$$\boxed{\text{Static pressure} = P + \rho gh}$$

$$\boxed{\text{Dynamic pressure} = \frac{1}{2} \rho v^2}$$

$$\text{That is } [S.P + D.P = \text{const}]$$

In a liquid flowing through a horizontal tube then 'h' remains constant and then we can write above formula as

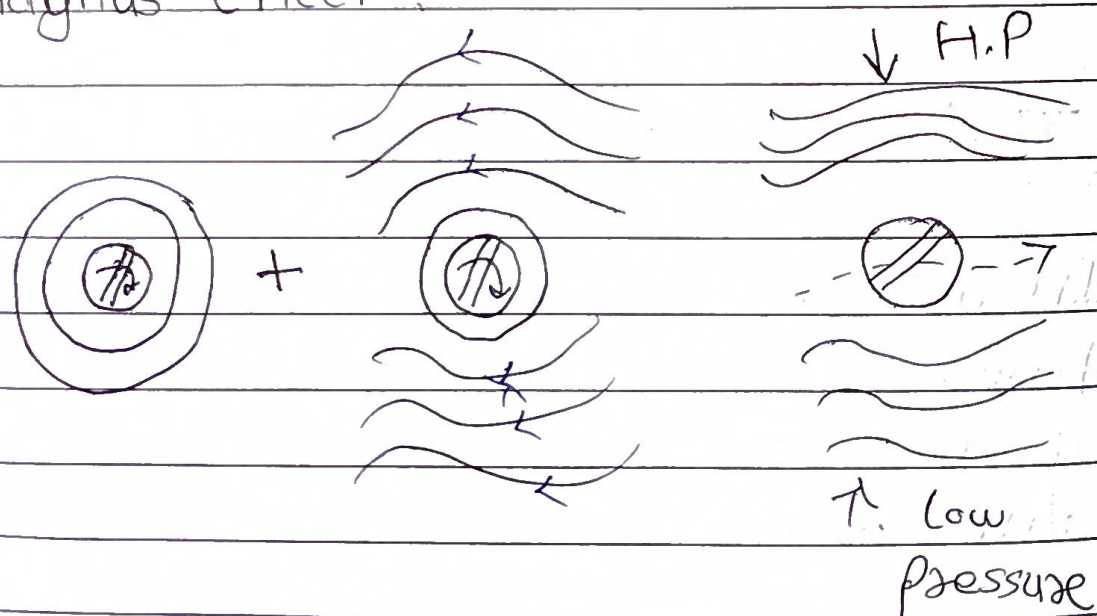
$$\boxed{P + \frac{1}{2} \rho v^2 = \text{Constant}}$$

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Dynamics Lift :-

Dynamic lift is the force that act on a body such as aeroplane wing, hydrofile or spinning ball by virtue of its motion through a fluid. It is responsible for the curved path of a spinning ball and lift an aircraft wing

Magnus Effect :-

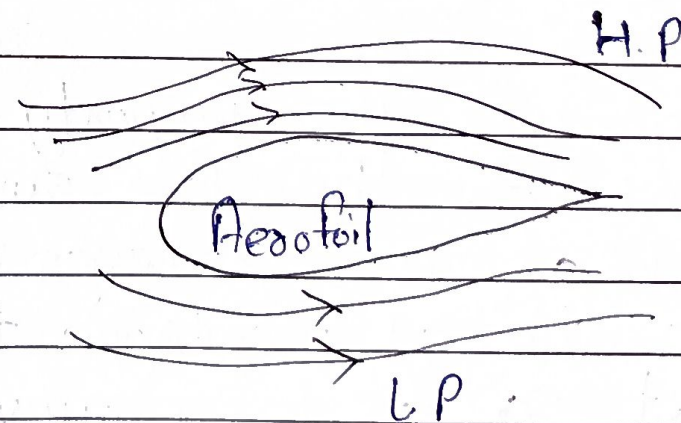


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The difference in lateral pressure which causes a spinning ball to take a curved path which convex towards greater pressure side, is called magnus effect.

Aerofoil (Lift of an aircraft wing) :-

It is the name given to a solid object shaped to provide an upward vertical force as it moves horizontally through air. This upward force (dynamic lift) make aeroplane fly



Cohesive force :-

It is the force of attraction between the molecules of the same substance

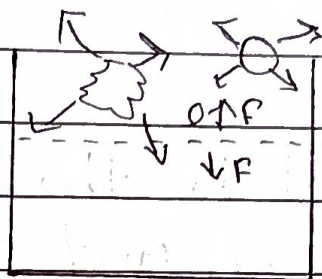
Adhesive force :-

It is the force of attraction between the molecules of the two different substances

E.g. force between ink & paper

Surface tension :- (σ)

Surface tension is the property by virtue of which the free surface of liquid at rest behaves like an elastic stressed membrane tending to contract so as to occupy minimum surface area.



$$\sigma = \frac{F}{l} \text{ N/m}$$

Some Phenomena based on surface

Tension :-

- i) Needle supported on water surface
- ii) Endless wet thread on a soap film
- iii) Rain drops are generally spherical and shape
- iv) Small mercury droplets are spherical and larger tend to flatten

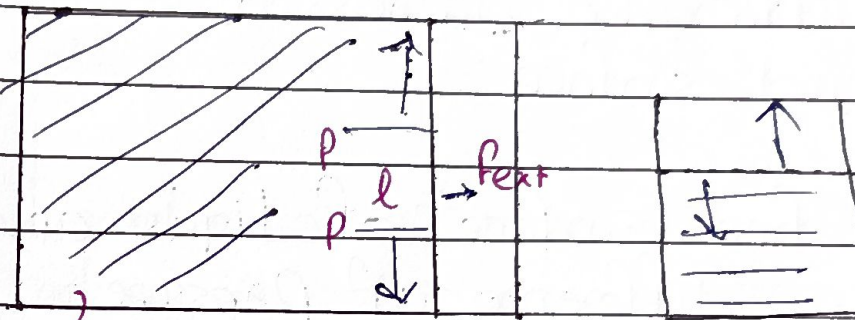
Surface Energy :

The extra energy possessed by the molecules of surface film of unit area compared to the molecules in the interior is called surface energy. It is equal to the work done in increasing the area of the surface film by the unit amount.

Surface Energy = $\frac{W.D}{\text{Increase in S.A}}$

Mathematically $= \frac{2\sigma l \cdot x}{2lx} = \sigma$

Surface energy = σ



Soap
film

$$F_{\text{ext}} = F$$

$$\text{Work done} = F_{\text{ext}} \cdot x = (2\sigma l) x$$

Surface Tension

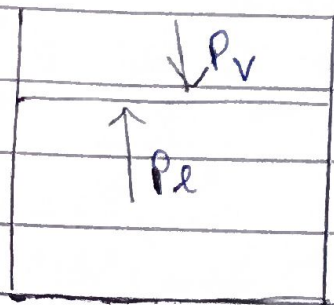
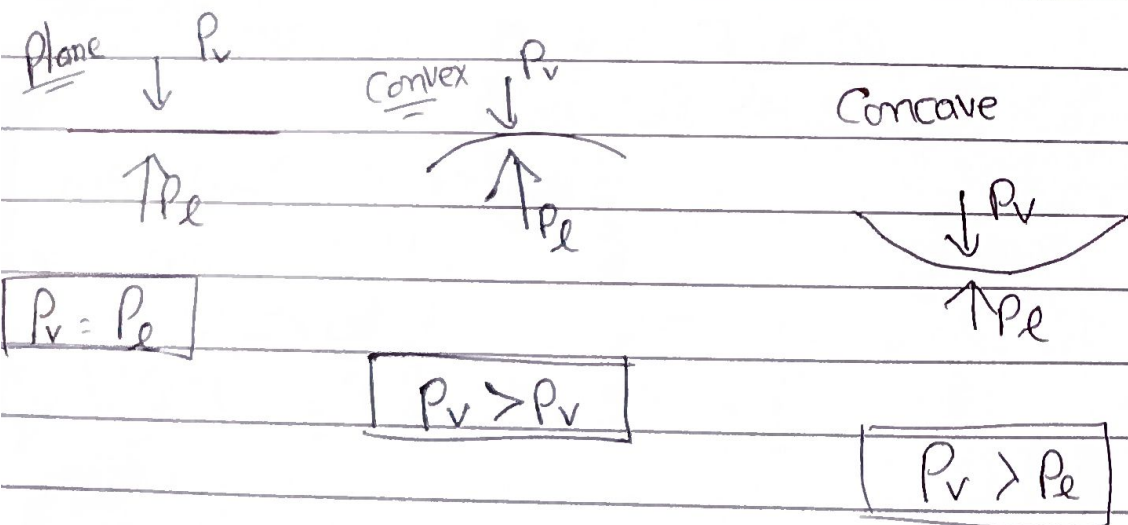
$$\sigma = \frac{F}{l} \quad \text{or} \quad F = \sigma l$$

For soap film
it has two
surfaces

$F = 2\sigma l$

Pressure Difference across a curved liquid surface :-

When the free surface of liquid curved there is a difference of pressure between the liquid side and the vapour side of the surface. We consider the three possible liquid surface



Excess Pressure inside a liquid drop :-

Consider a spherical liquid drop of radius ' R '. Let ' σ ' be the surface tension of the liquid. Due to its spherical shape there is an excess pressure ' p ' inside the drop over that on outside. This excess acts normally outwards.

$$\text{Initial surface Area} = 4\pi R^2$$

$$\begin{aligned} \text{Final surface Area} &= 4\pi (R + dR)^2 \\ &= 4\pi [R^2 + (dR)^2 + 2RdR] \\ &= 4\pi R^2 + 8\pi R dR \end{aligned}$$

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$$\Delta A = [4\pi R^2 + 8\pi R dr] - 4\pi R^2$$

$$\Delta A = 8\pi R dr$$

$$W = \sigma \Delta A = (8\pi R dr) \sigma$$

$$W = (8\pi R dr) \sigma$$

$$\text{work done} = F(dr)$$

$$F dr = 8\pi R dr \cdot \sigma$$

$$F = 8\pi R \cdot \sigma$$

Excess pressure :-

$$P = \frac{F}{4\pi R^2} = \frac{8\pi R \cdot \sigma}{4\pi R^2}$$

$$\boxed{P = \frac{2\sigma}{R}} \quad \text{for one free surface liquid drop}$$

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for air bubble

$$\boxed{P = \frac{2\sigma}{R}}$$

for soap bubble

It has two free surface

$$\boxed{P = \frac{4\sigma}{R}}$$

Capillarity :-

The latin word Capilla means hair. A tube of very fine (hair like) bore is called Capillary.



The phenomena of rise and fall of a liquid in a capillary tube in comparison to the surrounding is called capillarity.